Developing a Corrosion Model at the *QAR* Site to Enhance the Management of Submerged Archaeological Remains (Final Revision 5-16-2012)

Requested by:
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NC Sea Grant Mini-Grant Program Request Summary: The North Carolina Department of Cultural Resources/Underwater Archaeology Branch/*Queen Anne's Revenge* Shipwreck Project (*QAR*) request **$5,600** from North Carolina Sea Grant to initiate development of an *in-situ* corrosion model for iron artifacts at the *QAR* wreck site. The Beaufort Inlet shipwreck has been identified beyond doubt as Blackbeard's flagship *Queen Anne's Revenge* lost June 1718 in an upcoming article in Historical Archaeology (Volume 46, Number 4) co-authored by Mark U. Wilde-Ramsing and Charles R. Ewen. With regard to this and the many submerged archaeological sites throughout the world, the 2001 UNESCO Convention for the Protection of Underwater Cultural Heritage recommends *in situ* preservation as the first option. It may be many years before resources are in place to recover all QAR artifacts and conserve them in land based facilities but conservation can begin on the sea-bed. Research has shown that an indication of the inherent stability of an iron artifact can be monitored by testing its corrosion potential (E_{corr}) and improved with cathodic protection. Conditions at each wreck site are different so to apply this research for the management of the *QAR* site requires an understanding of factors influencing stability or corrosion at the site. This corrosion research project will gather data from all large iron artifacts (cannon and anchors) at the *QAR* shipwreck site, as well as on water quality and sulfate reducing bacteria in surrounding sediments to develop a corrosion model that will provide the basis for developing better strategies to manage this resource, both in and ex situ. NC Sea Grant funding will support vessel time, *in situ* monitoring/cathodic protection supplies, travel and per diem for staff divers and conference travel costs.

Problem Statement: Some preliminary testing has been conducted on several of the *QAR* large artifacts, which has demonstrated that it is possible to monitor the stability, and effectiveness of cathodic protection at the *QAR* site (Welsh 2010). Consistent and comprehensive data is now needed for the collection as whole in order to develop *QAR* site corrosion model. Without baseline information for each major iron artifact at the site and the surrounding environment, it is not possible to understand their relative stability; the impact re-deposition has on them; or the potential for improving its protection from ongoing corrosion. In turn, developing an *in situ* corrosion model, which takes into account these conditions, is not possible and management decisions unfounded.

Background: *In situ* corrosion studies on shipwrecks are becoming more common practice in Europe, Australia and the US (MacLeod 1995, Soerensen 1998, Gregory 2000, Matkinson 2002, Bartuli, 2008, Smith 2009, Steyne 2011). Corrosion of metal is an electrochemical process and its rate is sensitive to the temperature, salinity, dissolved oxygen, water movement and sulfate reducing bacteria in the surrounding sediment. An artifact that stands proud on the ocean floor is exposed to oxygen in seawater and will have a higher corrosion potential than an artifact that is buried in anaerobic sediment; the lower the corrosion potential the less the artifact will corrode due to a more stable form of iron. Researchers have proven that artifacts left *in situ* can be cathodically protected by attaching a sacrificial anode to improve the corrosion potential. Essentially the conservation process has been initiated on the bottom as chloride ions (salts) can be removed by changing the polarity of the iron (MacLeod 1987). In general, past *in situ* corrosion studies have studied the corrosion processes, mostly on the remains of iron-hulled vessels. A model to incorporate this research within a larger management strategy that involves scheduled recovery as proposed for *QAR* anchors and cannons has not been well developed.

State archaeological site 31CR314, the wreck of *Queen Anne's Revenge*, presently rests in 7 meters of water on the shoals of Beaufort Inlet. Full excavation of the *QAR* site began in 2006 and approximately 50% of the site has been recovered including thirteen cannon and one anchor. The goal is to have the entire site recovered as funding for recovery and conservation is available; however, the large iron artifacts - twelve cannon and three anchors – remaining on site will require large tanks and warehouse space, which at present is prohibitively limited at the conservation lab. The present policy for cannon and anchors within excavated areas is to move them to a nearby

holding area underwater where they are reburied and await recovery until space becomes available in the lab. To date four of the twelve cannon have been placed in the holding area with the and anticipation that the remainder will be re-deposited there during future recovery since the vast amount of smaller finds will take precedent when allocating conservation storage space. Currently, it is uncertain what the impact of this re-deposition has or will have on the large *QAR* artifacts in terms of corrosion and stability.

In the fall of 2008, an '*in situ* monitoring/conservation' research project was initiated on Anchor 3 (A3) which is partially buried under sediment (Welsh, 2010). '*In situ* monitoring' refers to testing the corrosion potential (E_{corr}) of the large iron artifacts in reference to a silver-silver chloride electrode and 'conservation' refers to cathodic protection. Due to the dynamic environment of the site much was learned from the trial and error of this study however a methodology was developed and recommendations for future studies to establish a corrosion model of the site were suggested. To build a corrosion model for the *QAR* site, researchers need additional water quality data, a sediment study for the presence of sulfate reducing bacteria and corrosion potential readings from as many large artifacts as attainable. A larger data set of corrosion readings will contribute to a more valid corrosion model. Limited water quality studies have been performed on the site so temperature, dissolved oxygen and salinity will be monitored while taking corrosion readings. Sediment studies for the presence of sulfate reducing bacteria have not been performed on site and will contribute greatly to the corrosion model.

Methods and Expected Outcomes: The model will be developed by obtaining data on all large artifacts before and after cathodically protected as well as conducting environmental parameter studies. Cannon and anchors are in varying conditions, some buried and some half exposed to the water column. A concretion thickness, pH measurement and corrosion potential (E_{corr}) reading will be taken on each artifact as per previous protocol in the A3 study (Welsh, 2010). Artifacts buried within bottom sediment will have zinc anodes attached and any artifact proud of the seafloor will require an aluminum anode. A pilot study to test for the presence of sulfate reducing bacteria will be conducted by East Carolina University professor of biology, Dr. Matthew Schrenk. Water quality data such as salinity, dissolved oxygen and temperature at varying depths will be obtained and tested on site.

The four cannon stored at the south end of the site and the south anchor(A4) are buried under approximately 1 meter of sediment; each needs to be uncovered so that readings can be obtained. Zinc anodes will be attached to all with the exception of one cannon which will serve as the control case for completely buried artifacts. The anchor and cannon in the main ballast pile need to be thoroughly investigated to assess anode attachment points. Some cannon may be too heavily concreted to allow anode attachment and hence only readings may be attainable; those cannon will act as the control case(s) for artifacts partially exposed to the water column. The conditions surrounding the north anchor (A3) will dictate the type of anode needed; however the existing anode will need to be replaced. Cannon in areas that have yet to be excavated will be assessed and cathodically protected. Readings will also be taken on mild steel and cast iron coupons previously placed in various conditions on site.

This grant will cover two one-week expeditions on site, with a third incorporated into the 2012 fall field season. The first expedition scheduled for early June 2012 when initial readings will be recorded for all artifacts and attach anodes to all possible candidates. During the fall expedition 2012 and Spring 2013 additional data sets will be collected to determine the relative stability of each artifact, how they are reacting to protective anodes, and provide *QAR* staff the basis to create a corrosion model to guide in situ preservation and recover schedules. The findings will be reported at the international ICOM-Metals conference in September 2013 in Scotland and submitted for publication in the conference proceedings.

Research Importance: The development of a corrosion model to guide resource managers overseeing the condition of *QAR* will be available for continued testing and refinement in the coming years. Ultimately this will lead to a new management strategy designed to determine which individual artifacts are most prone to continued deterioration and thus in need of accelerated recovery and transport to the conservation laboratory where it can receive more intense care. For those artifacts showing greater stability, the proposed cathodic protection will, in theory, also initiate the conservation process *in situ* by reversing the polarity of the iron artifact and in turn result in shortened conservation time and cost savings once it is recovered. This study will not only benefit the *QAR* site, but will contribute to the limited research regarding methods and techniques for *in situ* preservation which can be applied to many submerged archaeological sites. Professional dissemination to an international audience will further encourage testing and development of *in situ* preservation on threatened historic iron artifacts in coastal areas throughout the world. During expeditions to QAR and the USS Peterhoff (see paragraph below), investigators will accommodate Sea Grant personnel and members of the media for the purpose of raising public awareness and understanding of the importance of this in- situ corrosion study and Sea Grant support. Both shipwrecks represent important and highly recognized events during North Carolina's rich maritime history.

Requested Budget: $5,000.00 - The requested budget includes funds for shipboard time ($1,000.00), field researcher travel and per diem ($2,272.00), supplies for field ops and *in situ* corrosion monitoring ($1,028.00), and post data analysis and dissemination ($700.00). NC Marine Fisheries will furnish the research vessel, while UAB is providing technicians, divers, and graduate research supervision at no cost to the project.

USS Peterhoff cannon: Following discussions with Dr. Steve Rebach, we propose doing similar research on one and possibly two cannon on the USS *Peterhoff* lost in 1863 off the present day Fort Fisher Historic Site in the Wilmington area. While we don't consider these cannon to serve as control for our QAR research, they would provide important cases for comparative purposes. These are the only other cannon within the North Carolina coastal waters that are currently available for easy study. A couple of other advantages: the Navy is interested in the study and has given us the go ahead; the UAB main office is located at Fort Fisher and can provide vessel and personnel support at minimal cost; and there is and will be heightened awareness of the Civil War shipwrecks off of Fort Fisher during the sesquicentennial. USS *Peterhoff* was also the focus of early underwater archaeology investigations in 1963 that lead to the development of UAB, which now leads the nation in submerged site management. Data gathering will follow the schedule for QAR research with three expeditions: spring/summer 2012, fall/winter 2012/13, and spring/summer 2013.

Additional Funding Requested: $600.00 - The cost for three visits to study the Peterhoff cannon includes $484.75 for mileage and meals for researcher travel and $116.25 for vessel gas. UAB staff, vessel, and equipment will more than match Sea Grant funding.

Receipt of Funds: $5,600.00 - Sea Grant funding on behalf of UAB will be received through the North Carolina Department of Cultural Resources, Sarah Dozier, Chief Financial Officer, 4505 Mail Service Center, Raleigh NC 27699-4605. To reach Ms. Dozier by telephone call: 919-807-7278 or by e-mail: **sarah.dozier@ncdcr.gov**

Attachments: 2-page resume for PI's; Site map and in-situ corrosion photos; Reference bibliography